Supply Chain Networks, Labor, and Resilience

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National Vaccine Advisory Committee (NVAC)
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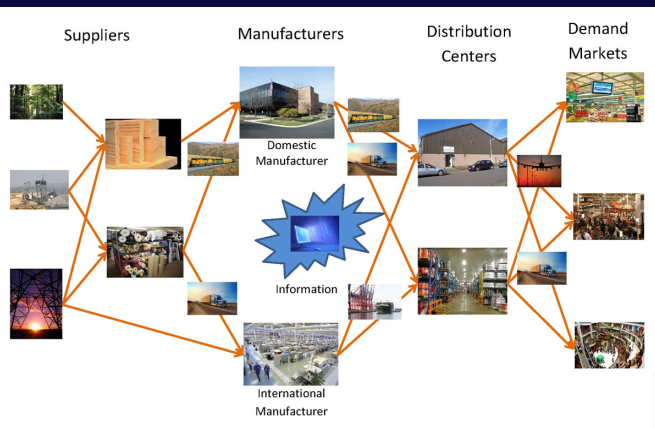
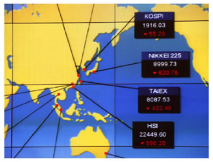
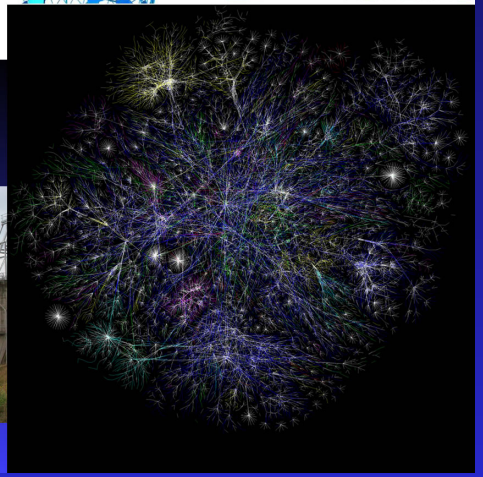
Many thanks for the opportunity to speak to you today!

This talk is dedicated to essential workers, who have sustained us in the COVID-19 pandemic.

I Work on the Modeling of Network Systems





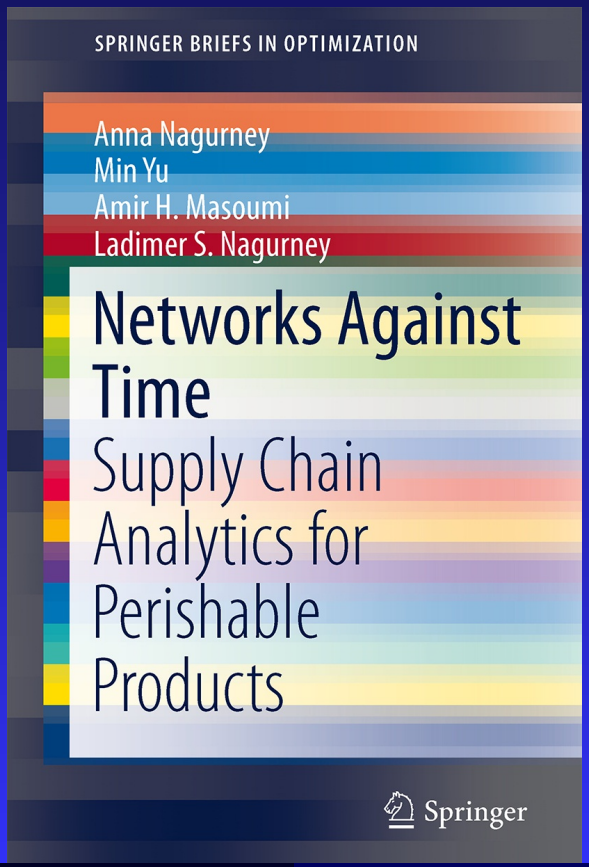


Much of My Recent Research Has Been on Supply Chains

Some of My Books

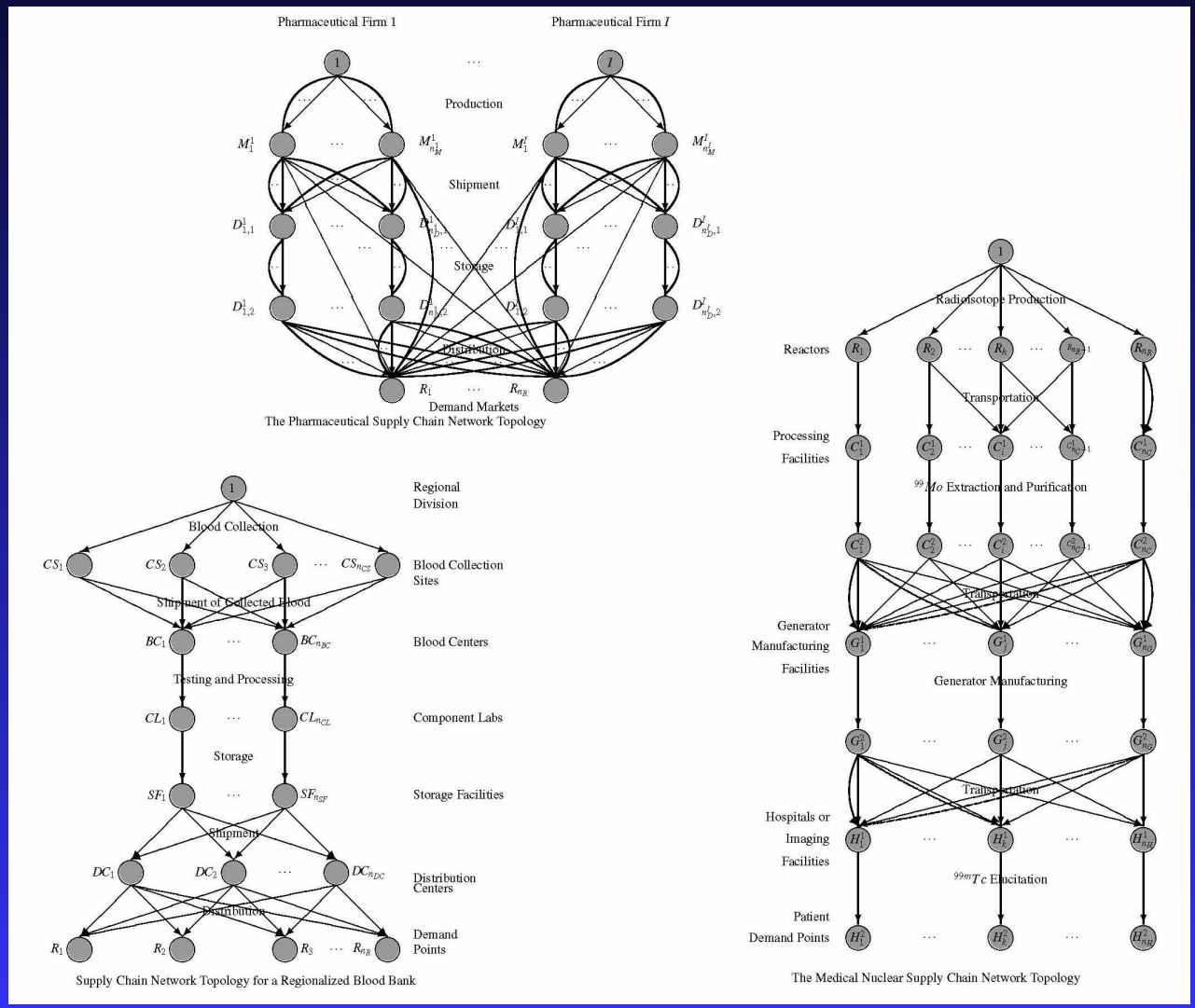
A Multidisciplinary Approach

In our research on perishable and time-sensitive product supply chains, we utilize results from physics, chemistry, biology, and medicine in order to capture the perishability of various products over time from healthcare products such as blood, medical nucleotides, vaccines and pharmaceuticals to food.

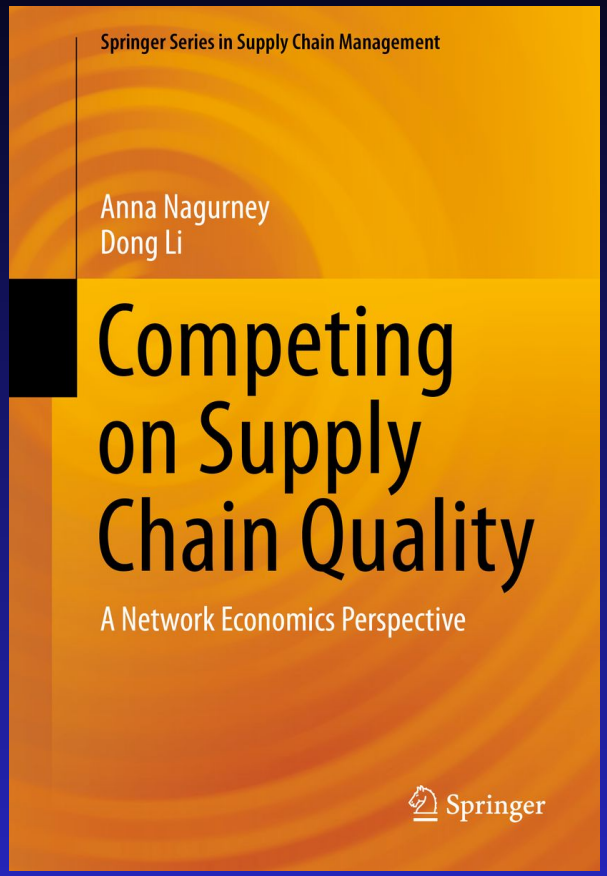


Some of the Supply Chain Network Topologies

Applications to pharmaceutical supply chains, blood and medical nuclear ones.

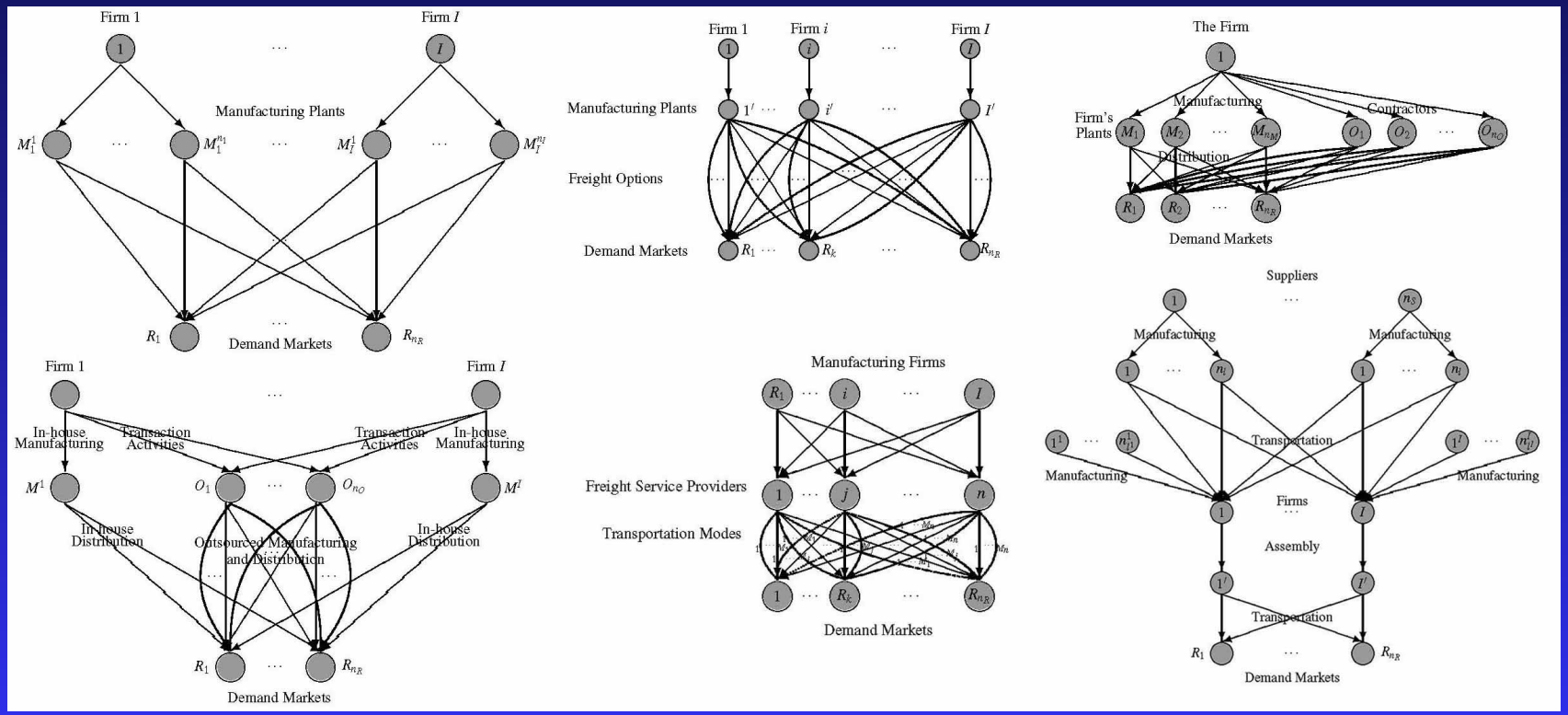


Research on Quality is Related to That on Perishability



Recent US Government investigation report suggests Emergent Biosolutions destroyed almost 400 million doses of COVID-19 vaccine due to failure to meet or maintain quality standards. It also worked to conceal quality issues from the FDA.

In the book, we present supply chain network models and tools to investigate, amongst other topics, information asymmetry, impacts of outsourcing on quality, minimum quality standards, applications to industries such as pharma, freight services and quality, and **the identification of which suppliers matter the most to both individual firms' supply chains and to that of the supply chain network economy**.



Vaccine Supply Chain Components and Exporters

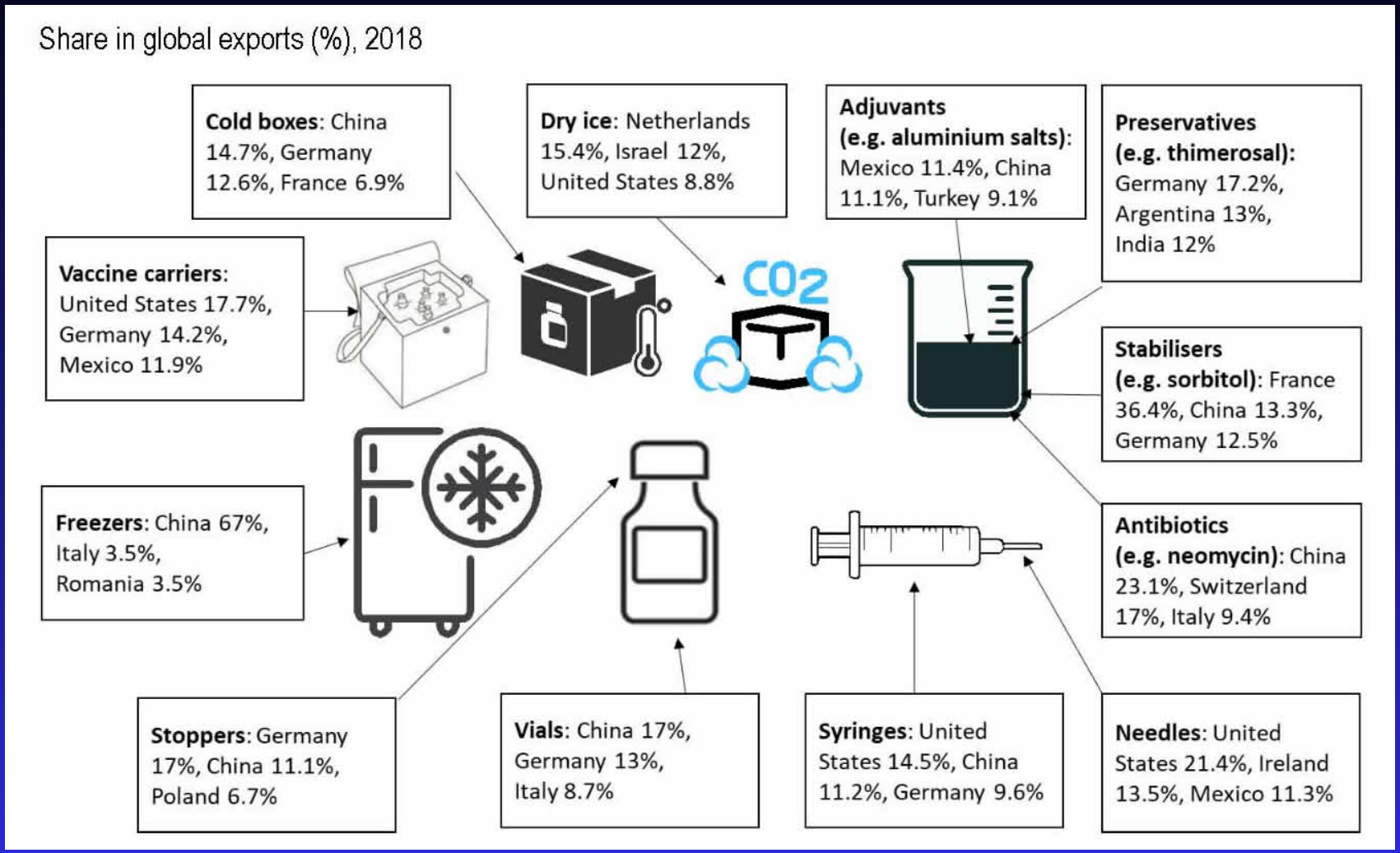


Figure: Top exporters of items needed in the production, distribution and administration of vaccines, OECD

It's All About People

A major research theme of ours in the COVID-19 pandemic is the inclusion of labor in supply chains, using optimization and game theory.

ORMS TODAY informs membership magazine

NEWS FEATURES PODCASTS

January 29, 2021 in Supply Chain Networks

In the End, It's All About People

COVID-19 vaccine production reveals dependency on supply chains, labor workforce in the U.S.

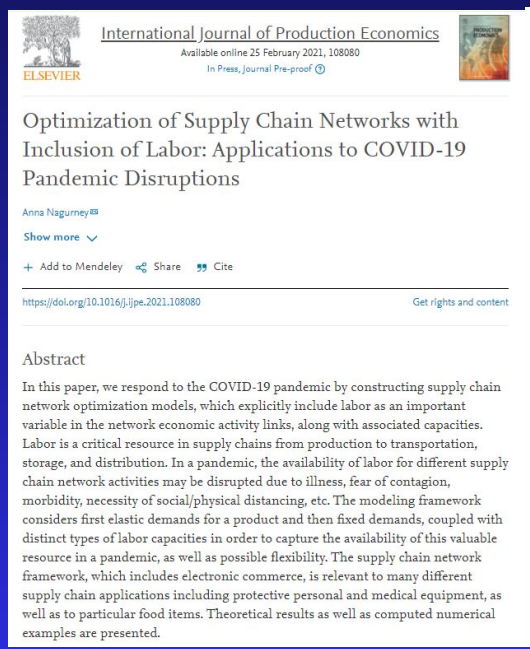
By Anna Nagurney

SHARE: PRINT ARTICLE: https://doi.org/10.1287/orms.2021.01.17

The COVID-19 pandemic has dramatically revealed how dependent we are on supply chains and the availability of labor. Without the human element, meatpacking plants cannot function; fresh produce cannot be picked; grocery stores cannot be shelved; PPEs cannot be produced and distributed; and products cannot be delivered to our homes through e-commerce. Also, COVID-19 vaccine production may lack the human resources to ensure product quality and efficacy, as well as its distribution and ultimate administration into our arms. Without healthcare workers to administer COVID-19 vaccines, the battle against the coronavirus cannot be won. Many hospitals are already short-staffed because of the pandemic.

Research and Publications

In a series of papers we constructed supply chain network models with labor that included productivity factors and constraints on labor in order to identify the impacts of disruptions and to suggest possible mitigation procedures.



International Journal of Production Economics

Available online 25 February 2021, 108080

In Press, Journal Pre-proof

Optimization of Supply Chain Networks with Inclusion of Labor: Applications to COVID-19 Pandemic Disruptions

Anna Nagurney

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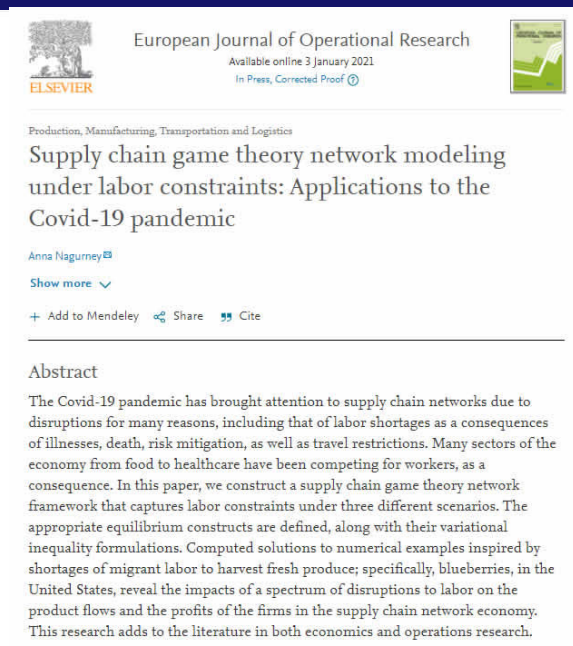
Abstract

In this paper, we respond to the COVID-19 pandemic by constructing supply chain network optimization models, which explicitly include labor as an important variable in the network economic activity links, along with associated capacities. Labor is a critical resource in supply chains from production to transportation, storage, and distribution. In a pandemic, the availability of labor for different supply chain network activities may be disrupted due to illness, fear of contagion, morbidity, necessity of social/physical distancing, etc. The modeling framework considers first elastic demands for a product and then fixed demands, coupled with distinct types of labor capacities in order to capture the availability of this valuable resource in a pandemic, as well as possible flexibility. The supply chain network framework, which includes electronic commerce, is relevant to many different supply chain applications including protective personal and medical equipment, as well as to particular food items. Theoretical results as well as computed numerical examples are presented.



European Journal of Operational Research

Available online 3 January 2021

In Press, Corrected Proof

Production, Manufacturing, Transportation and Logistics

Supply chain game theory network modeling under labor constraints: Applications to the Covid-19 pandemic

Anna Nagurney

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Abstract

The Covid-19 pandemic has brought attention to supply chain networks due to disruptions for many reasons, including that of labor shortages as a consequences of illnesses, death, risk mitigation, as well as travel restrictions. Many sectors of the economy from food to healthcare have been competing for workers, as a consequence. In this paper, we construct a supply chain game theory network framework that captures labor constraints under three different scenarios. The appropriate equilibrium constructs are defined, along with their variational inequality formulations. Computed solutions to numerical examples inspired by shortages of migrant labor to harvest fresh produce; specifically, blueberries, in the United States, reveal the impacts of a spectrum of disruptions to labor on the product flows and the profits of the firms in the supply chain network economy. This research adds to the literature in both economics and operations research.

European Journal of Operational Research

Editors' Award

2021

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in recognition of an outstanding contribution to the quality of the Journal with sincere thanks and very best wishes from the Editors of European Journal of Operational Research and the Directors of Elsevier B.V.

Prof. Roman Slowiński
Co-ordinating Editor of EJOR

Simon Jones
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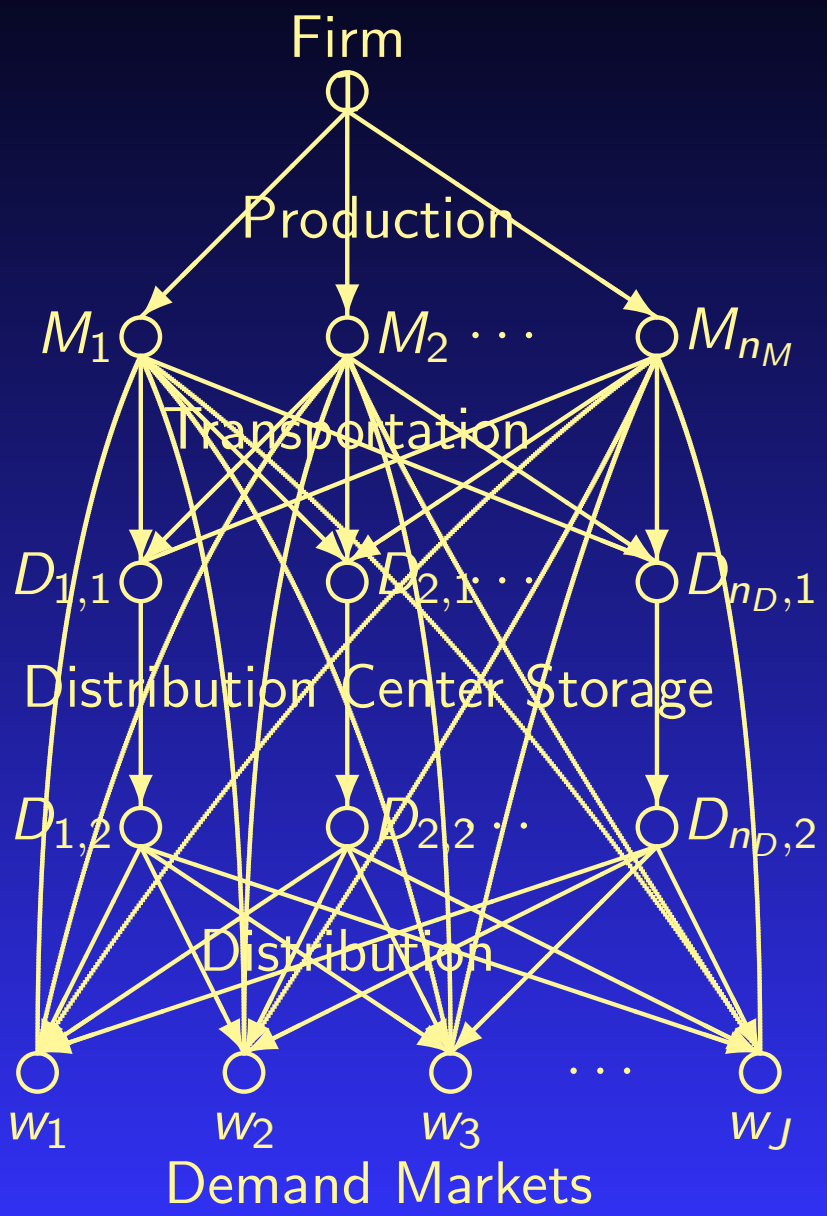
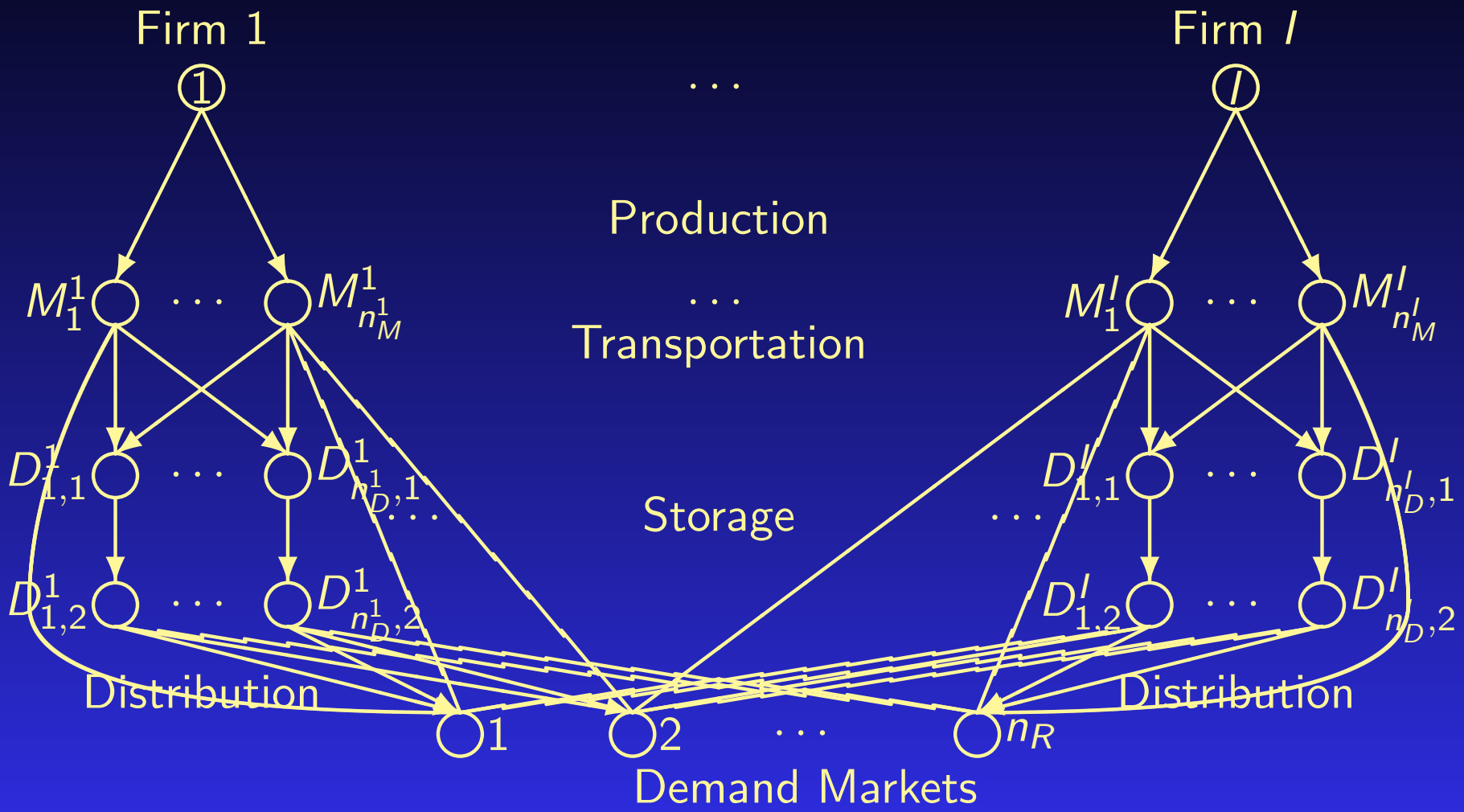
Supply Chain Model with Different Labor Constraints



Game Theory Supply Chain Network Model with Labor

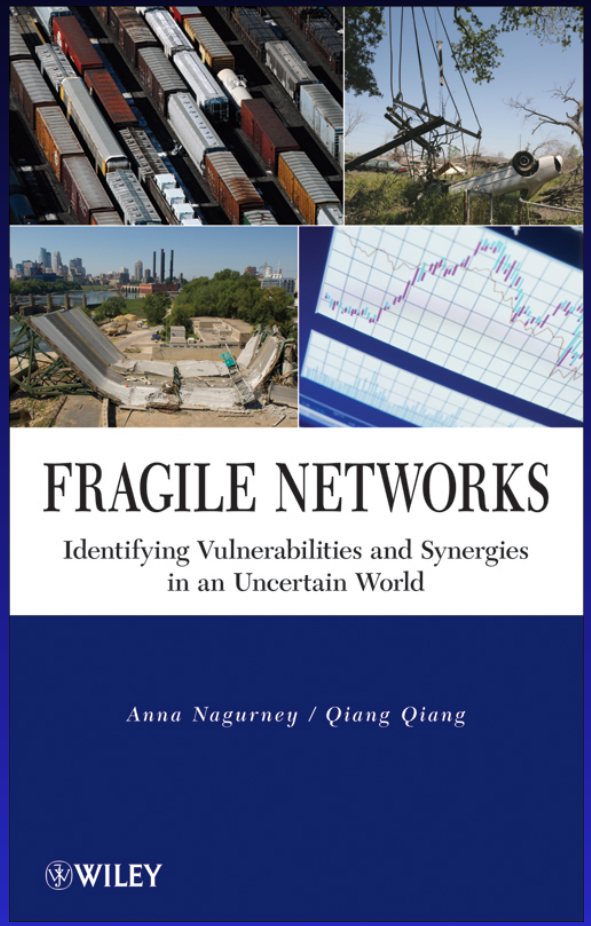


Supply Chain Models with Different Labor Constraints

Our findings include:

1. **Lack of labor in a single supply chain link, even in a freight service one, can have major negative impacts on supply chain network product flows and prices.**
2. **Having appropriate healthcare pandemic mitigation processes and procedures in place is essential to continuing operations.** With even one manufacturing plant closed, the prices can rise at the demand markets.
3. **Reduction in labor availability can result in a significant increase in product prices at the consumer level.**
4. **Even in the case of reduced labor availability, having alternative distribution channels can be very helpful.**
5. **Having the flexibility of labor being able to be reallocated across supply chain network activities can enable enhanced profits.**

Resilience of Supply Chain Networks with Labor



How to quantify the resilience of a supply chain network in general and, specifically, with respect to disruptions in labor availability and productivity.

Resilience of Supply Chain Networks with Labor

To appear in *Resilience Findings*

Resilience of Supply Chain Networks to Labor Disruptions

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June 6, 2022

ABSTRACT: This study introduces a supply chain network efficiency measure for networks with labor and associated bounds on labor availability. It also proposes two resilience measures with respect to (1) labor availability disruptions and (2) labor productivity disruptions. Solving five distinct supply chain network examples, we find (1) a free movement of labor across the supply chain network results in a higher efficiency of the supply chain as well as a higher resilience, (2) a reduction in labor productivity can impact the supply chain network efficiency and the corresponding resilience, and (3) the presence of electronic commerce escalates the efficiency of the supply chain network but diminishes resilience.

Keywords: Supply chains; Networks; Labor; Supply chain performance efficiency; Resilience

1

Defense Critical Supply Chain Networks and Risk Management with the Inclusion of Labor: Dynamics and Quantification of Performance and the Ranking of Nodes and Links

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Handbook for Management of Threats, Security and Defense, Resilience and Optimal Strategies
Dr. Konstantinos Balomenos (Hellenic Ministry of National Defense, Gen. Dir. of Natl Defense Policy),
Major Antonios Fytopoulos (2nd Airfield Support Battalion - Hellenic Army General Staff), and
Distinguished Professor Panos Pardalos (University of Florida), Editors
Springer Nature

Abstract: The efficient and effective performance of defense critical supply chain networks is essential to both national and global security. Disruptions to supply chains, heightened in the COVID-10 pandemic, and now further exacerbated because of growing geopolitical and other risks, as well as Russia's war against Ukraine, have garnered the attention of decision-makers and policymakers, including those in the defense sector. In the paper, a rigorous methodological framework is presented for defense critical supply chain networks in the form of a defense supply chain network economy that captures the behavior of defense firms, which care about revenues as well as risk, and which includes the important labor resources and associated constraints. Variational inequality theory is used to provide alternative formulations of the governing Nash Equilibrium conditions, with a dynamic model counterpart used for the construction of an easy to implement algorithm that yields closed form expressions at each iteration of the defense product path flows and the Lagrange multipliers associated with the bounds on labor hours available on supply chain links. A defense supply chain network efficiency /performance measure is proposed and an associated importance indicator for supply chain network components. A resilience measure is also given that quantifies the resilience of the defense supply chain network economy to disruptions in labor. The modeling and algorithmic framework, as well as the measures proposed, are then illustrated via numerical examples.

Keywords: Defense; Supply Chains; Networks; Resilience; Labor; Game Theory; Variational Inequalities

Resilience of Supply Chain Networks with Labor

Supply chain network efficiency measures for networks with labor and associated bounds on labor availability are introduced in both optimization and game theory contexts and two resilience measures with respect to (1) labor availability disruptions and (2) labor productivity disruptions.

Solving multiple distinct supply chain network examples, we find:

(1). a free movement of labor across the supply chain network results in a higher efficiency of the supply chain as well as a higher resilience;
(2). a reduction in labor productivity can impact the supply chain network efficiency and the corresponding resilience, and
(3). the presence of electronic commerce escalates the efficiency of the supply chain network but diminishes resilience.

More information on our work can be found on the Supernetwork Center site.

https://supernet.isenberg.umass.edu/